

Stratigraphic Evidence of Environmental Change on Easter Island

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INTRODUCTION

THE SMALL SIZE AND isolation of Easter Island would be expected to make its human population especially sensitive to the effects of any alterations in the environment. Such alterations might include climatic change (especially drought), geological change (such as volcanic eruption or change in sea level), and biotic change (such as forest destruction or the introduction of a new plant or a new disease). If ecological disaster were to strike, the people had, until recent times, nowhere to go; they simply had to sit it out, possibly with catastrophic results.

It is therefore not surprising that environmental change has sometimes been postulated to help explain some of the more bizarre features of Easter Island. For instance, McCall (1976) suggested that a major drought could have contributed to a breakdown of social organization leading to the cessation of statue building about A.D. 1680. Mulloy (1970), however, believed that the end of statue building was related to the destruction of the last remaining forest on the island. He argued that large timbers were essential for moving and erecting the statues, and that forest would have been essential to provide these timbers. Driftwood would have been inadequate in quality and quantity. The importance of timber for the moving of statues was supported by the experiments of Heyerdahl (1957), and the former existence of forest, although at an unknown date, was suggested by the preliminary palynological results of Selling (in Heyerdahl 1961). The poverty of the present flora makes it out of line with the flora of other oceanic islands of comparable size, geology, altitude, and climate, and van Balgooy (1960) concluded that the island's exceptional isolation and other natural ecological features were inadequate to explain this circumstance: many species must have become extinct on the island as a result of human ac-

tivity. Opinions differ, however, on this point. Skottsberg (1956) thought that isolation would explain most of the poverty of the flora, and van Balgooy himself reversed his earlier conclusion in a later paper (1971).

The present paper is the first in a series intended to provide direct evidence of the environmental history of Easter Island by the study of sediments preserved in the three crater swamps on the island (Fig. 1). This paper concerns the stratigraphy and preliminary dating of the three sites; later papers will discuss the vegetational history derived from pollen analysis of the sediments, along with more detailed dating.

STRATIGRAPHY AND PRELIMINARY DATING

Rano Raraku (c. 75 m above sea level)

This is possibly the most interesting of the three swamps, because with few exceptions all the giant statues of Easter Island (numbering about 600) were quarried on the outer or inner slopes of the crater, and 25 statues still stand, complete except for their eye sockets, close to the swamp. The crater is bowl shaped, with a fairly low rim to the north and west, the rim in these areas being covered in deeply weathered rock and soil. To the south and east the rim rises higher, exposing the volcanic tuff, which forms cliffs about 100 m high on the outer side. All the statue quarries are on the south or southeast side of the crater. Until a few years ago (e.g., Heyerdahl and Ferdon 1961), the crater contained a substantial lake with a marginal swamp of *Scirpus riparius* and *Polygonum acuminatum*. There is no clear indication of erosion outside the lowest point on the crater rim, which suggests that the lake has not recently overflowed. It may, however, have stood at a higher level at some time in the past, for traces of lake deposit were seen up to at least 7 m above the present level. Within the last 20 years, the lake level has been artificially lowered by pumping out water for stock. A large trench was cut through the lowest part of the crater wall, on the southwest side, to enable the pumping to take place. These actions, while doubtless of economic value, have had serious ecological repercussions that may well have damaged the historical record preserved in the sediments. The lake level was lowered by about 2 m, with the result that *Scirpus riparius* has spread over the whole surface; there is no open water left. The lake mud exposed at the edge has dried out and oxidized, and its pollen content has probably been partially destroyed. The swamp vegetation in this area has been replaced by dryland grasses, but the vegetation is distinct from that above the previous lake level. In places the dried mud is suffering gully erosion, and the eroded particles are contaminating the present-day swamp deposit with derived material.

A transect of three borings was made along a line running out into the swamp from the southeastern edge. The outermost borehole coincided with a change to wetter conditions and more open vegetation. This is possibly the edge of the former open water. The results of the boring are shown in Figure 2. None of the boreholes reached bedrock. The deposit simply became progressively stiffer near the base, so that boring became more difficult. The lower part of each borehole penetrated a thick deposit of fine detritus mud, an indication of open water conditions at the time of sedimentation. This deposition was interrupted on two occasions by the accumulation of a 1-cm thick band of grey silt, which on microscopic examination can be seen to contain glassy fragments and is almost certainly a volcanic ash. Nearer the surface, the mud becomes coarser, indicating the overgrowth of the lake by swamp. These uppermost deposits include, at all three boreholes, a layer containing inorganic material that is of particular interest. In borehole RRA 1, this layer con-

sisted of a dark chocolate-brown mixture of plant detritus, humus, and clay, 31 cm thick. Traces of clay continued downward for a further 31 cm. In borehole RRA 3, this horizon consisted of a 10-cm thick layer of plant detritus, clay, and sand. Multiple borings at this point produced red sand in some cases and yellow sand in others. In borehole RRA 2, nearest the bank, the layer appears to be duplicated. The upper section consists of sand, silt, and reworked mud and the lower of gravel, silt, and reworked mud; the two are separated by coarse detritus mud. Such duplication is consistent with the occurrence of floating mats of swamp vegetation (Tauber 1958). Some of the inorganic material is washed on top of the mats, while some penetrates beneath.

The complete core from borehole RRA 3 was collected for laboratory analysis. The material from 12.35 to 12.45 m depth was subjected to ^{14}C assay and gave a date of $35,260 \pm 980 - 870$ B.P. (SRR-1352). The $\delta^{13}\text{C}$ value was -22.8‰ , which suggests that inorganic-derived carbonate is absent from the sediment and that there is no resultant error in the date.

Rano Aroi (c. 425 m)

Since it is at a higher altitude, Rano Aroi may well have had an ecological history somewhat different from that of Rano Raraku. Close to the highest point of the island (510 m), it is a relatively small crater containing a swamp about 150 m in diameter, dominated by *Scirpus riparius*, other Cyperaceae, and *Polygonum acuminatum*. There is a small outflow stream, almost the only surface flowing water on the island.

Only two borings were made at this site, and neither was continued to the base of the deposit, because of the shortage of time. The lowest deposit encountered (Fig. 3) was a spongy organic deposit that was interpreted in the field as a coarse detritus mud, but that on reexamination in the laboratory appears to be a sedge peat. The occurrence of this material 9 m below the present surface could suggest a formerly lower water level. Above this deposit there is a mixture of coarse detritus and finer material which is far less elastic than the earlier deposit. This would be consistent with a rise in water level. Nearer the surface, there is a gradual return to material similar to that found at the base, which can be accounted for by the infilling of the swamp to its present surface with no further change in water level. It is interesting to note that a layer of inorganic material was recorded at borehole ARO 2. This consisted of a brown clay, 3 cm thick, at a depth of 2.4 m.

A complete core from borehole ARO 1 was taken for laboratory analysis, and the portion 11.35 m to 11.45 m was submitted for ^{14}C assay. The resulting date of $37,680 \pm 1200 - 1040$ B.P. (SRR-1353) is associated with a $\delta^{13}\text{C}$ value of -14.6‰ , which is anomalous and suggests the date may be too old because of old carbonate error. Although there is no limestone in the vicinity (or indeed anywhere on the island), the possibility of carbon dioxide of juvenile origin reaching a volcanic site cannot be excluded. Even living plants adjacent to active craters have given ^{14}C ages up to 400 years B.P. (M. Stuiver, personal communication). In any case, some of the volcanic rocks of the island do contain small amounts of carbonate (Chubb 1933). It is therefore concluded that this date is not very reliable, although the site is clearly of considerable age.

Rano Kao (c. 110 m)

The largest crater on Easter Island, this is clearly a caldera. The interior walls of the caldera slope down at a regular angle (estimated from contours) of c. 37° , except where a

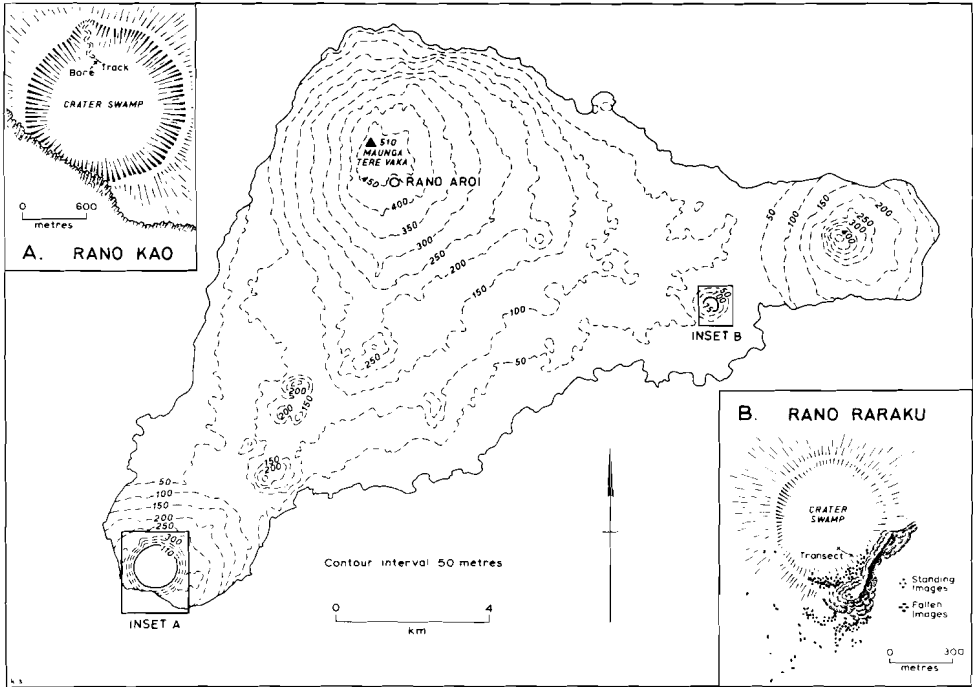


Fig. 1 Easter Island, to show location of the three crater swamps. Insets: Rano Kao and Rano Raraku. After Mulloy (1970), Routledge (1919), and McCoy (1976).

RANO RARAKU

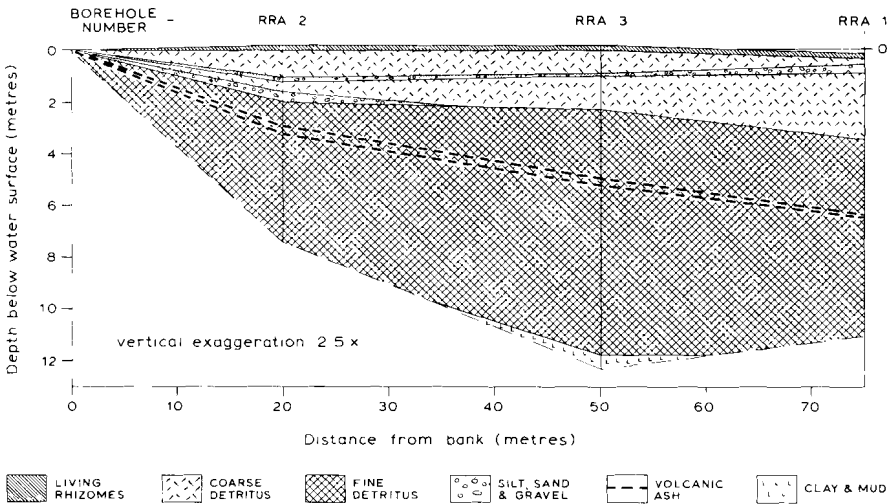


Fig. 2 Stratigraphic record at Rano Raraku. Vertical exaggeration $\times 2.5$.

RANO AROI

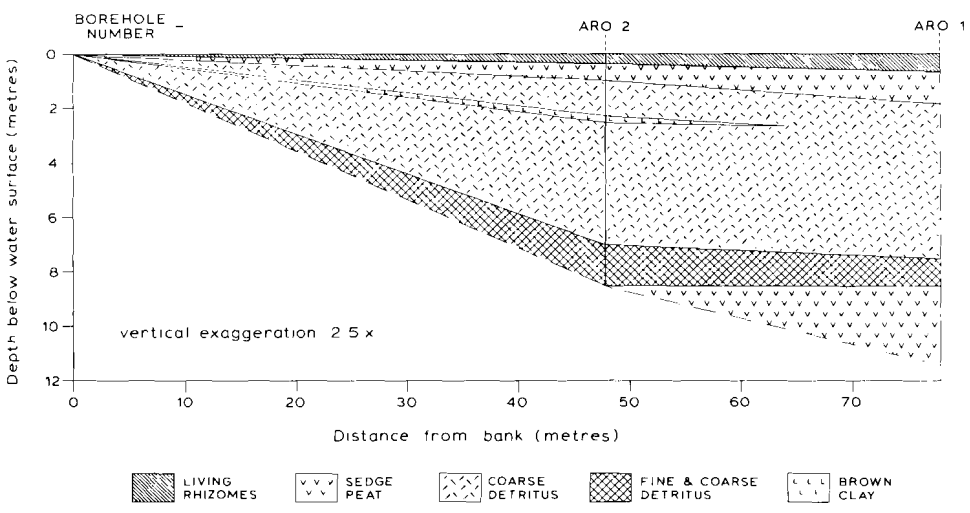


Fig. 3 Stratigraphic record at Rano Aroi. Vertical exaggeration $\times 2.5$.

RANO KAO

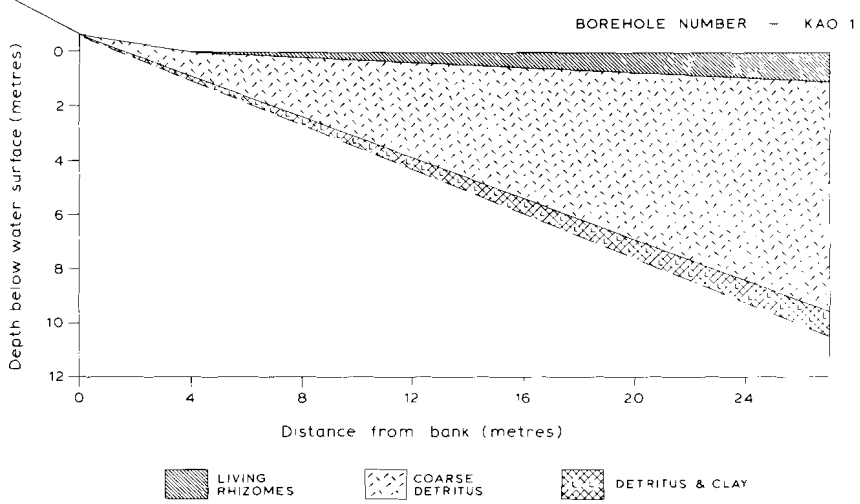


Fig. 4 Stratigraphic record at Rano Kao, without vertical exaggeration. The slope above the swamp was estimated from the contours shown in Fig. 1. The marginal slope was estimated by eye in the field.

landslip on the north-northwest side has reduced the slope to c. 28° . The circular crater swamp, with a diameter of 1 km, bears a largely floating vegetation of *Scirpus riparius*, although there is a continuous rim of *Polygonum acuminatum*. The site is dangerous to work on, and in addition time was pressing, so that only one boring was made here (Fig. 4). It was made 27 m from the bank on the north-northwest side of the swamp at the foot of the landslip, and was the furthest point from the bank that could be reached without deep wading or swimming. A very coarse detritus mud was recorded throughout the upper 9.5 m of this core. There was then a gradual change to grey clay, and the core bottomed on hard rock at 10.5 m. No inorganic layers were seen apart from the basal material.

The core was retained for laboratory analysis and the section 9.30 to 9.40 m submitted for ^{14}C assay. The resulting date of 990 ± 70 B.P. (SRR-1351) is associated with a $\delta^{13}\text{C}$ value of -28.2‰ , which suggests no anomaly. The date is consistent with the extreme coarseness and high water content of the sediment, implying a very rapid growth rate.

DISCUSSION

The Rano Raraku transect was deliberately placed on the side of the swamp directly below the statue quarries. It was argued that the construction and removal of the statues would have required such an amount of human activity as partially or totally to destroy the vegetation nearby. The expected result of this deforestation would have been soil erosion, and the eroded soil should have accumulated in the lake. The inorganic layer shown in Figure 2 may well be this deposit. The color of the material (red in some borings, yellow in others) suggests that it has experienced oxidizing conditions, and is entirely consistent with present soils around the lake. The particle size of the material at borehole 2 (sand and silt) is also what might be expected from soil washed into the edge of a lake. The clay fraction would be washed further out—as in fact it is, to borehole RRA 1. Borehole RRA 3 is, appropriately, intermediate, yielding both sand and clay.

Similar inwashed layers of inorganic material are now recognized, in many different parts of the world, as the result of forest clearance by man. In Britain, for instance, Simmons et al. (1975) recorded many such layers in peat bogs, and a tropical example is provided by the excavations of Golson and Hughes (1976) in New Guinea.

It is extremely interesting that a similar inorganic layer is recorded at Rano Aroi in one borehole—significantly the one nearest the bank. This would be consistent with the forest clearance being an occurrence widespread over the island rather than localized. Of course, there is as yet no suggestion that the inwashings at the two sites have to be contemporaneous.

The absence of the inorganic layer in the Rano Kao core could have several explanations. Either forest clearance did not occur there (and there is still some scrub, albeit of the introduced *Melia azederach*, on the slope above the sampling site), or it occurred before 990 B.P. Alternatively, the hard rock bottom could represent a boulder in material which slumped into the site following clearance, in which case the major clearance possibly ended just before 990 B.P. That major landslipping did once occur near the point where the core was taken is evident from the aerial photograph of Rano Kao (McCoy 1976). Only further fieldwork can make it possible to decide between these alternatives.

Other aspects of the stratigraphy at the three sites can be explained in terms of "normal" ecological successions, with one exception. The change from peat to coarse detritus mud at Rano Aroi is anomalous. It could be accounted for in several possible ways. The

peat might have developed on a floating mat of organic material that became waterlogged and sank. Alternatively, the water level might have risen. In that case, the earlier water level must have been well below the level of the present outflow. Possibly the earlier outflow was blocked by a landslide. Another possibility is a change in climate, which could have taken the form of either a reduction in temperature, leading to reduced evaporation and hence a rise in water level, or an increase in precipitation, or both. There seems to be no good reason why a floating mat bearing living vegetation should sink, and the likelihood of a landslide is not great because there is no inorganic matter washed in at that level. Against a change in climate it must be pointed out that no related change was noted at Rano Raraku, although parallel changes might be expected in a site so close at hand. On the other hand, Rano Raraku was apparently a fairly deep lake until relatively recently, and a change in water level might not have been very significant ecologically. There remains, therefore, a strong possibility that the climate changed.

CONCLUSIONS

There is evidence in the stratigraphy for two possible ecological changes in the history of Easter Island. The earlier of these, although it remains undated, is a possible change from drier conditions, evidenced by the basal peat at Rano Aroi, to moister ones more like those of the present day. This evidence may be interpreted in other ways, however: for example, by the blocking of the exit from the crater by a minor landslide.

The later change, for which there is much better evidence, is of a major decline in vegetation cover, leading to erosion of soils and the redeposition of some of this material in two of the three crater swamps. In other parts of the world such a change is usually forest clearance, and it seems likely that this was the case on Easter Island also.

Further evidence for both these changes, currently being sought by pollen analysis and further dating of the cores, will be reported in a later paper.

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